

***Trophic State Indices.*** Trophic state indices characterize lakes based on nutrient concentrations, chlorophyll *a* concentrations, secchi disk transparency and other parameters. The most widely known is Carlson's Trophic State Index (TSI) which compares chlorophyll *a* concentration, secchi disk transparency, and total phosphorus concentration. This index was developed for lakes that are phosphorus limited. An index is obtained for each of the three parameters and these indices allow for comparisons of the trophic status of lakes. These indices should not be averaged (Carlson 1977). The following expressions use Carlson's method to calculate the TSI (Carlson and Simpson 1996, as cited in USEPA 2000b):

$$\begin{aligned} \text{TSI (CHL)} &= 30.6 + 9.81 \ln (\text{CHL}) \quad (\text{chlorophyll } a, \text{ in mg/m}^3) \\ \text{TSI (SD)} &= 60 - 14.41 \ln (\text{SD}) \quad (\text{secchi disk readings, in m}) \\ \text{TSI (TP)} &= 4.15 + 14.42 \ln (\text{TP}) \quad (\text{total phosphorus, in mg/m}^3) \end{aligned}$$

Carlson's index uses algal biomass as the basis for trophic state classification. Chlorophyll *a*, secchi depth, and total phosphorus independently estimate algal biomass. The trophic continuum is based on a log transformation of secchi disk values. Carlson's index ranges from 0-100 and each 10-unit division of the index corresponds to a halving or doubling of secchi depth. Total phosphorus is usually inversely correlated with transparency and so a doubling of the total phosphorus usually corresponds to a halving of secchi depth. Chlorophyll *a* is a better predictor of algal biomass than total phosphorus or secchi depth. A northern temperate lake would be classified as oligotrophic with a TSI below 30, mesotrophic with a TSI between 40 and 50, and eutrophic with a TSI between 50-60. A TSI index above 70 characterizes hypereutrophic lakes (Carlson and Simpson 1996, as cited in USEPA 2000b). As shown in Table C-1, Big Bear Lake falls under eutrophic, but borders on hypereutrophic status.

**Table C-1. Carlson's Trophic State Index for Big Bear Lake**

	<b>TSI (TP)</b>	<b>TSI(chla)</b>	<b>TSI (TN)</b>	<b>TSI(SD)</b>
Minimum	53	35	53	40
Maximum	64	73	64	61
Mean	56	55	56	50

Note: The values used to calculate the TP, TN, and SD indices were from 6/01 to 4/02 prior to any herbicide treatment. The chla values were from 6/01 to 10/01 which corresponds to the growing season and were obtained prior to any herbicide application.

Other researchers added a nitrogen index to be used when water bodies were nitrogen limited (Kratzer and Brezonik 1981, as cited in USEPA 2000b). The formula used to calculate this nitrogen index is shown below:

$$\text{TSI(TN)} = 54.45 + 14.43 \ln (\text{TN}) \quad (\text{nitrogen values must be in mg/L})$$

Variations in this index as well as Carlson's phosphorus index simultaneously might indicate that neither nitrogen or phosphorus are limiting, while variations in only Carlson's phosphorus index might indicate nitrogen limitation (Carlson and Simpson 1996, as cited in USEPA 2000b). As seen in Table C-1, three of the TSI indices are very similar while the secchi depth TSI is somewhat lower. Because the indices are similar, it implies that the lake is phosphorus limited and that algae dominate light attenuation (Carlson and Simpson 1996, as cited in USEPA 2000b).

Carlson's TSI is based only on algal biomass and does not account for macrophyte biomass. If the lake is macrophyte-dominated, the trophic state could be underestimated using Carlson's index. For example, Canfield et al. (1983) using Carlson's TSI classified one lake in Florida as oligotrophic, even though hydrilla covered 80% of the lake. The loss of hydrilla in the lake shifted the system to plankton and only then did Carlson's TSI classify the lake as eutrophic. To account for macrophytes, Canfield et al. 1983 developed an equation to estimate the total submersed macrophyte biomass in a lake. The equation is:

$$\text{TSMB} = \text{SA} \times \text{C} \times \text{B}$$

TSMB = total submersed macrophyte biomass (kilograms)

SA = lake surface area (square meters)

C = percent cover of submersed aquatic macrophytes

B = average biomass collected with a sampler (kilograms/square meter)

To then estimate the total amount of phosphorus associated with macrophytes, the variables in the equation above were used with the measured total phosphorus content in plant tissue. The total phosphorus in the macrophytes is summed with the total phosphorus estimated in the water column to obtain the total phosphorus content of the lake. This value can then be substituted into Carlson's TSI (TP) index. So, instead of just using water column concentration of total phosphorus, the relative contribution of phosphorus from the macrophytes will also be considered in calculating the trophic state of a lake. Because Big Bear Lake was classified as eutrophic using Carlson's TSI, it is not necessary to utilize the methodology of Canfield et al. (1983) in determining trophic state.

## **ATTACHMENT A**

### **Resolution No.**

To be submitted at a later date